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AIR BUBBLER SYSTEM DESIGN FOR THE 140 FOOT WYTM.(U)
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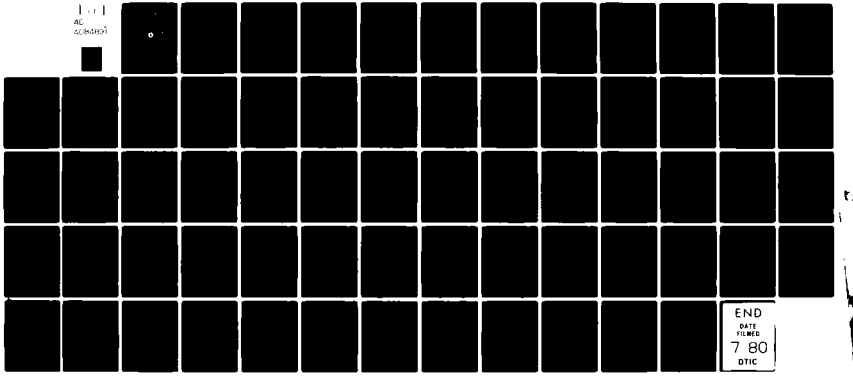

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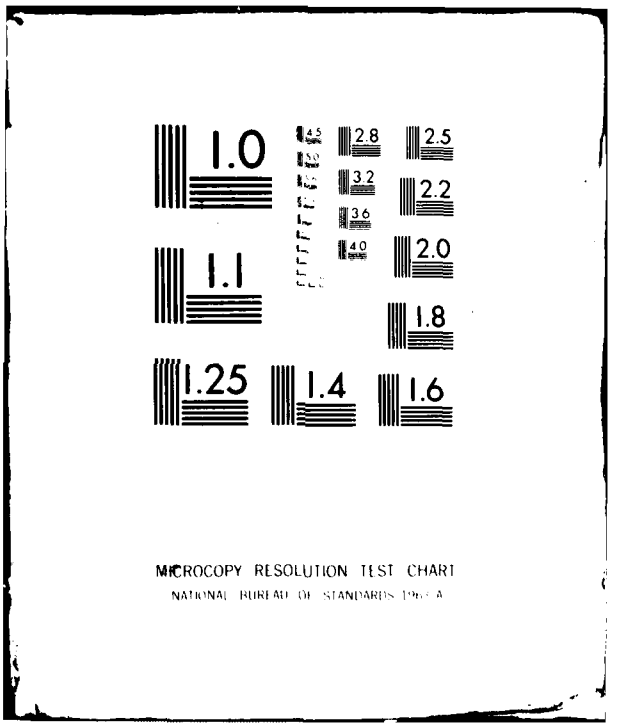
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NATIONAL BUREAU OF STANDARDS 1963-A

Report No. CG-E-01-80

LEVEL II

13

AIR BUBBLER SYSTEM DESIGN FOR THE 140-FOOT WYTM

JANUARY 1976

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard

NAVAL ENGINEERING DIVISION
WASHINGTON, D.C. 20593

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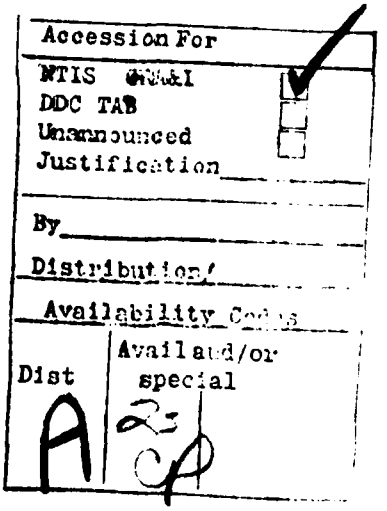

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Technical Report Documentation Page

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16. Abstract

The 140' class of Coast Guard Cutters are equipped with an air bubbler hull lubrication system for ice breaking. The air bubbler system reduces ice friction against the cutter's hull plating. This report describes the air bubbler system on this class cutter, gives its operating characteristics, and its design history.

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Report No. 202C-3

AIR BUBBLER SYSTEM DESIGN FOR THE 140-FOOT WYTM

By

E.J. Lecourt

January 1976

FINAL REPORT

CONTRACT NO. DOT-CG-50383-A

Prepared for

Department of Transportation
United States Coast Guard
Office of Engineering
400 Seventh Street, S.W.
Washington, D.C. 20590

TABLE OF CONTENTS

NOMENCLATURE

d = manifold diameter

f = friction coefficient

l = manifold length between orifices

q = flow rate from orifice

A_0 = orifice area

C_D = discharge coefficient

K = manifold flow coefficient

Q_1 = flow rate approaching orifice location

V_1 = fluid velocity approaching orifice location

ΔP = change in pressure

ΔP_0 = pressure differential across orifice

ρ = mass density

I. DESCRIPTION OF THE SYSTEM

The air bubbler system designed for the 140-foot WYTM consists of four manifolds, an air compressor driven by a diesel engine, and the necessary piping and valves.

The two forward or bow manifolds consist of two 6" x 4" rectangular tubes which are located on the center line below the molded keel line from the forefoot at about Frame 9 to Bulkhead 32. Six orifices are located in the outboard side of each tube. The location and the size of each orifice is listed in Table I.

The two aft manifolds consist of two air ducts located within the hull, outboard of the 9' Buttock, and extending from Bulkhead 32 to Bulkhead 61. The width of the duct is 8 inches and the height of the inboard side is approximately 8 inches. The hull plating forms the bottom of the duct. The dimensions of the inboard and outboard sides of the duct vary with the slope of the hull. These manifolds each have eight orifices through the hull plating; the location and size of each orifice is listed in Table II.

The spacing of the orifices in the manifolds described above is 6 feet. An alternate design with orifices located every 4-1/2 feet was also prepared. The number, size, and location of the orifices for these alternate manifolds are listed in Tables A-1 and A-2 of Appendix A.

The air for the bubbler system is supplied by an air compressor with a capacity of 7500 SCFM at 9 psig. The compressor will be driven by a diesel engine rated at 350 HP. The diesel-compressor will be located in a van on the main deck above the motor room.

The piping system consists of a 12" main which divides in the engineroom into two 10" mains. The branches to each manifold are 8" pipe. A schematic of the piping system is shown in Figure 1.

In each branch, a straight run has been provided with fittings for a flowmeter, pressure gage, and thermometer. These will be utilized for installing instruments for testing the effectiveness of the bubbler system.

The design of the system provides four modes of operation:

1. all four manifolds
2. two bow manifolds only
3. two starboard side manifolds only
4. two port side manifolds only.

Motor operated butterfly valves are located at each manifold to permit changing the mode of operation.

The first mode is the normal mode for operations in ice. The second mode allows all of the air to be supplied to the bow manifolds if this should prove to be more effective. The third and fourth modes are for maneuvering in restricted waters, providing the capability of moving the bow to the right or left. The characteristics of the system for each mode of operation are explained in the following section.

TABLE I.

FORWARD MANIFOLDS, PORT AND STARBOARD

6-FOOT ORIFICE SPACING

Orifice No.	Location (Frame No.)	Diameter (inches)
1	10 - 11	1.875
2	14 - 15	1.875
3	18 - 19	2.000
4	22 - 23	2.000
5	26 - 27	2.125
6	30 - 31	2.125

SUPPLY AT AFT END OF MANIFOLD.

TABLE II.

AFT MANIFOLDS, PORT AND STARBOARD

6-FOOT ORIFICE SPACING

Orifice No.	Location (Frame No.)	Diameter (inches)
1	32 - 33	1.438
2	36 - 37	1.562
3	40 - 41	1.562
4	44 - 45	1.562
5	48 - 49	1.562
6	52 - 53	1.562
7	56 - 57	1.562
8	60 - 61	1.438

SUPPLY BETWEEN ORIFICES NO. 4 AND 5.

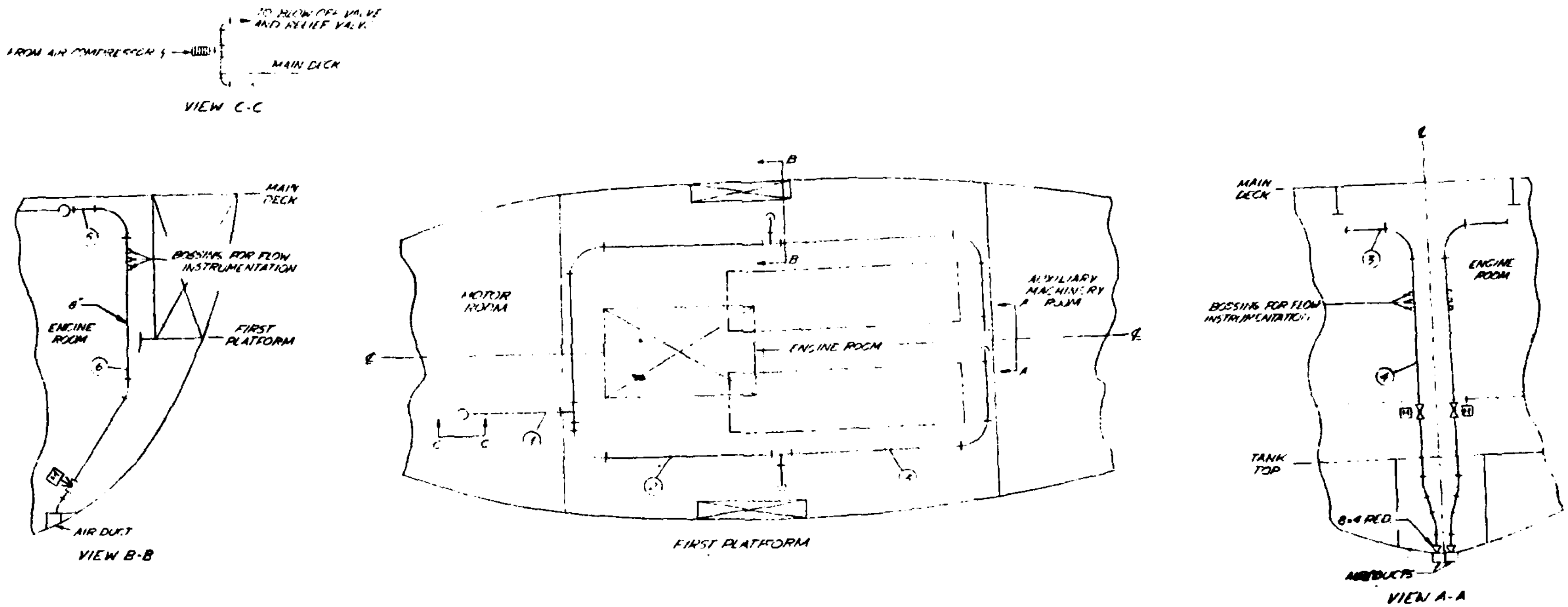

FIGURE 1. SCHEMATIC OF THE AIR PIPING SYSTEM.

II. OPERATING CHARACTERISTICS

The characteristics of the air bubbler system for each mode of operation are summarized in Table III. The air flow and pressure at the compressor are determined by the characteristics of the compressor, the piping system, and the manifolds.

Typical compressor characteristics are shown in Figures 2 and 3. Air flow versus discharge pressure is shown in Figure 2, and power versus discharge pressure is shown in Figure 3. The operating pressure of the system is limited by the power of the diesel engine.

The air flow through each orifice is a function of the pressure in the manifold, the hydrostatic pressure outside the manifold, and the diameter of the orifice. Calculations have been performed to determine the air flow characteristic versus manifold pressure, and the results are presented in graphical form in Figures 4, 5, 6, 7, and 8. A computer program was used to perform the calculation, and the printout is included in Appendix B.

The pressure drop in the piping system has been calculated for each mode of operation and is tabulated in Table III.

In modes 3 and 4, the total air flow cannot be supplied to the manifolds on one side of the ship without exceeding the 9 psig pressure limit imposed by the torque limit of the diesel engine. It is, therefore, necessary to provide a blow-off of 750 SCFM through a special valve in order to keep the pressure at 9 psig.

The characteristics of the alternate manifolds with 4-1/2-foot spacing are almost identical. Graphs of the characteristics are included in Appendix A, and the supporting calculations are included in Appendix B.

TABLE III
OPERATING CHARACTERISTICS FOR EACH MODE

MODE	AIR FLOW (SCFM)					PRESSURE (PSIG)			POWER (HP)
	Bow Manifold Stbd Side	Bow Manifold Port Side	Aft Manifold Stbd Side	Aft Manifold Port Side	Total Air Flow	Bow Manifold	Aft Manifold	Air Compressor	Diesel Engine
1.	1700	1700	2050	2050	7500	5.7	5.7	6.4	250
2.	3750	3750	—	—	7500	7.8		9.0	325
3.	3550	—	3200	—	6750*	7.5	7.7	8.9	325
4.	—	3550	—	3200	6750*	7.5	7.7	8.9	325

* Blow-off required equal to 750 scfm

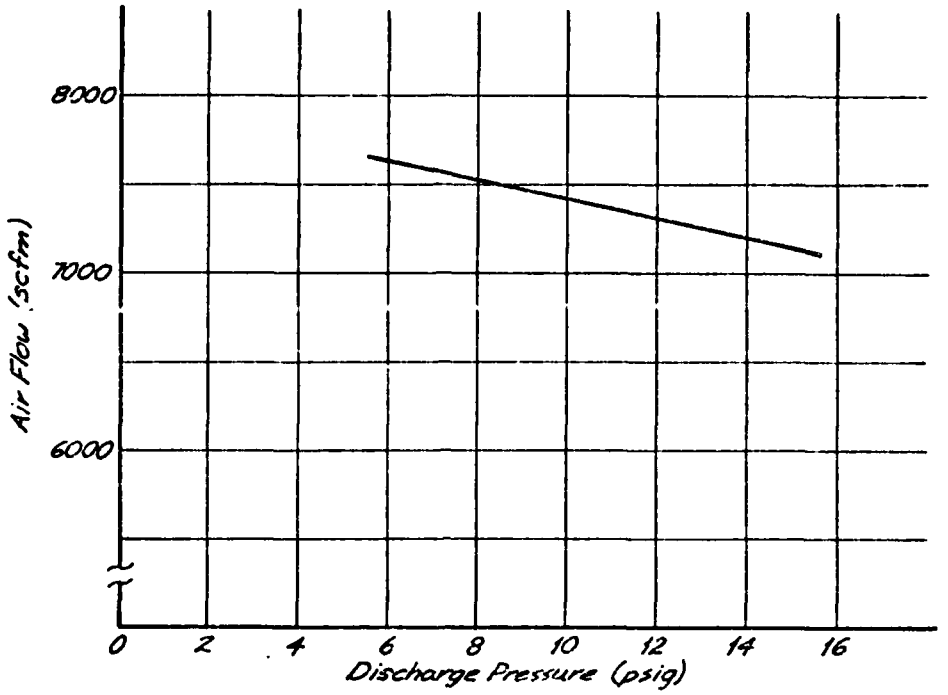

FIGURE 2
AIR FLOW VS DISCHARGE PRESSURE
FOR INGERSOLL-RAND TYPE L AXI 178 x 28 COMPRESSOR AT 1770 RPM

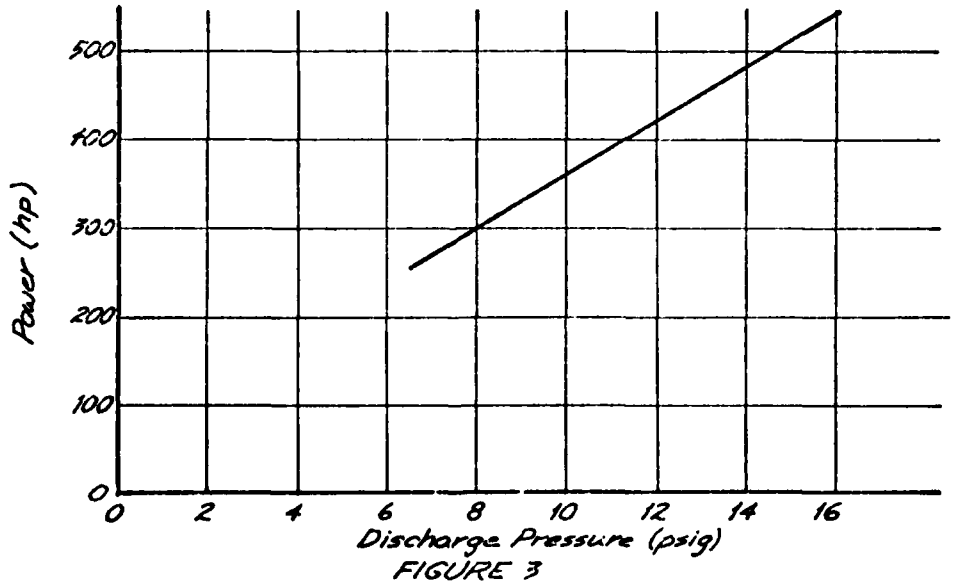

FIGURE 3
POWER VS DISCHARGE PRESSURE
FOR INGERSOLL-RAND TYPE L AXI 178 x 28 COMPRESSOR AT 1770 RPM

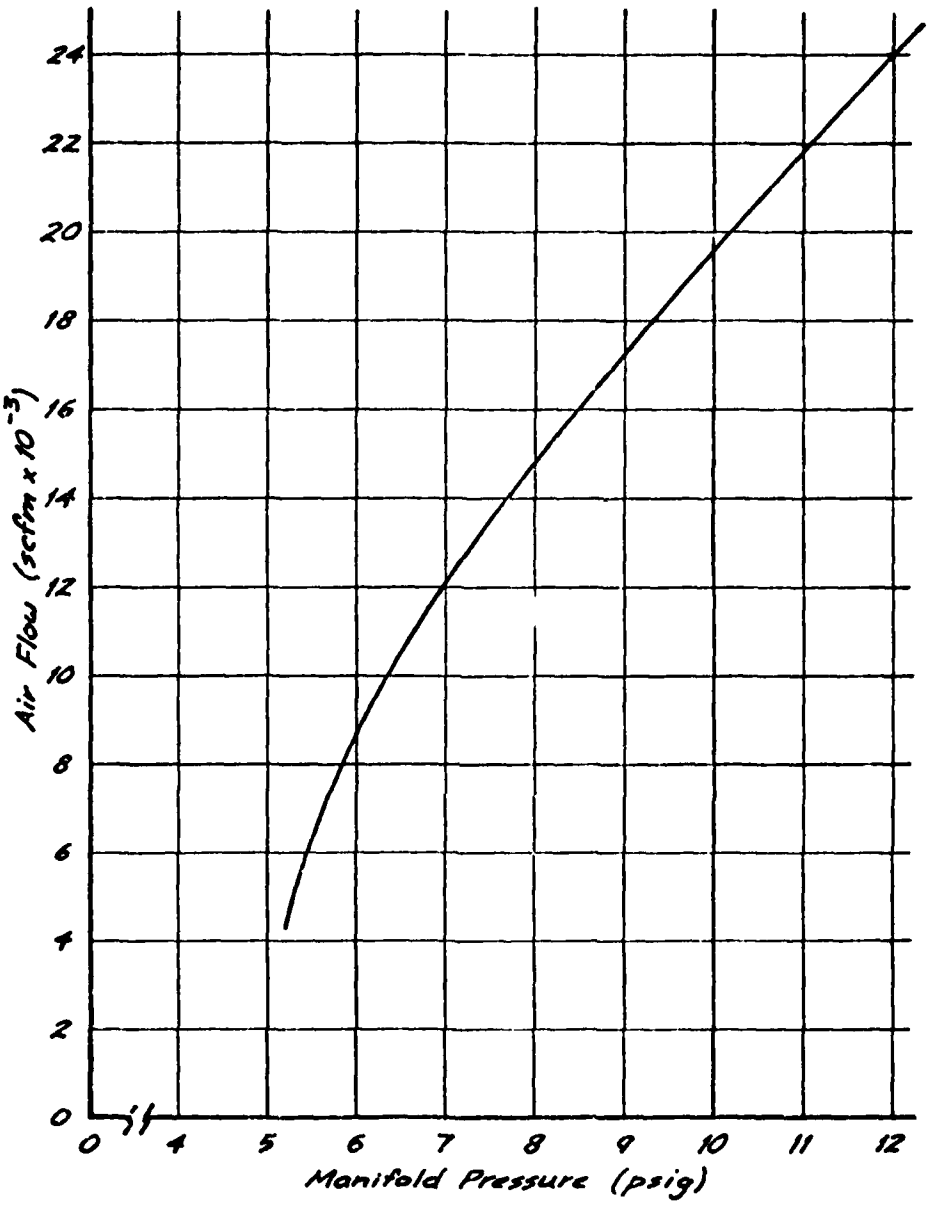

FIGURE 4

AIR FLOW CHARACTERISTIC WITH ALL MANIFOLDS

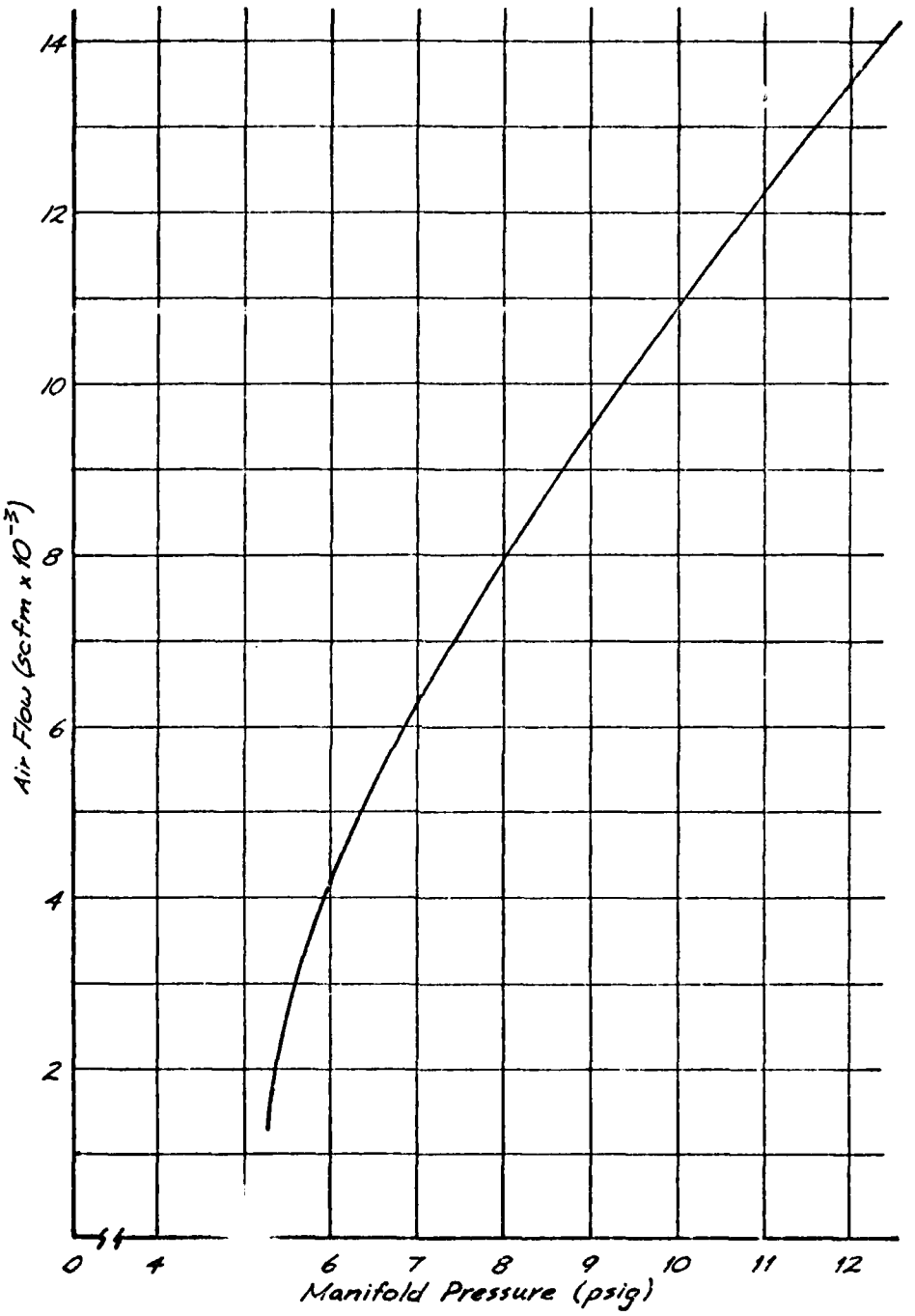

FIGURE 5
AIR FLOW CHARACTERISTIC WITH TWO EGW MANIFOLDS

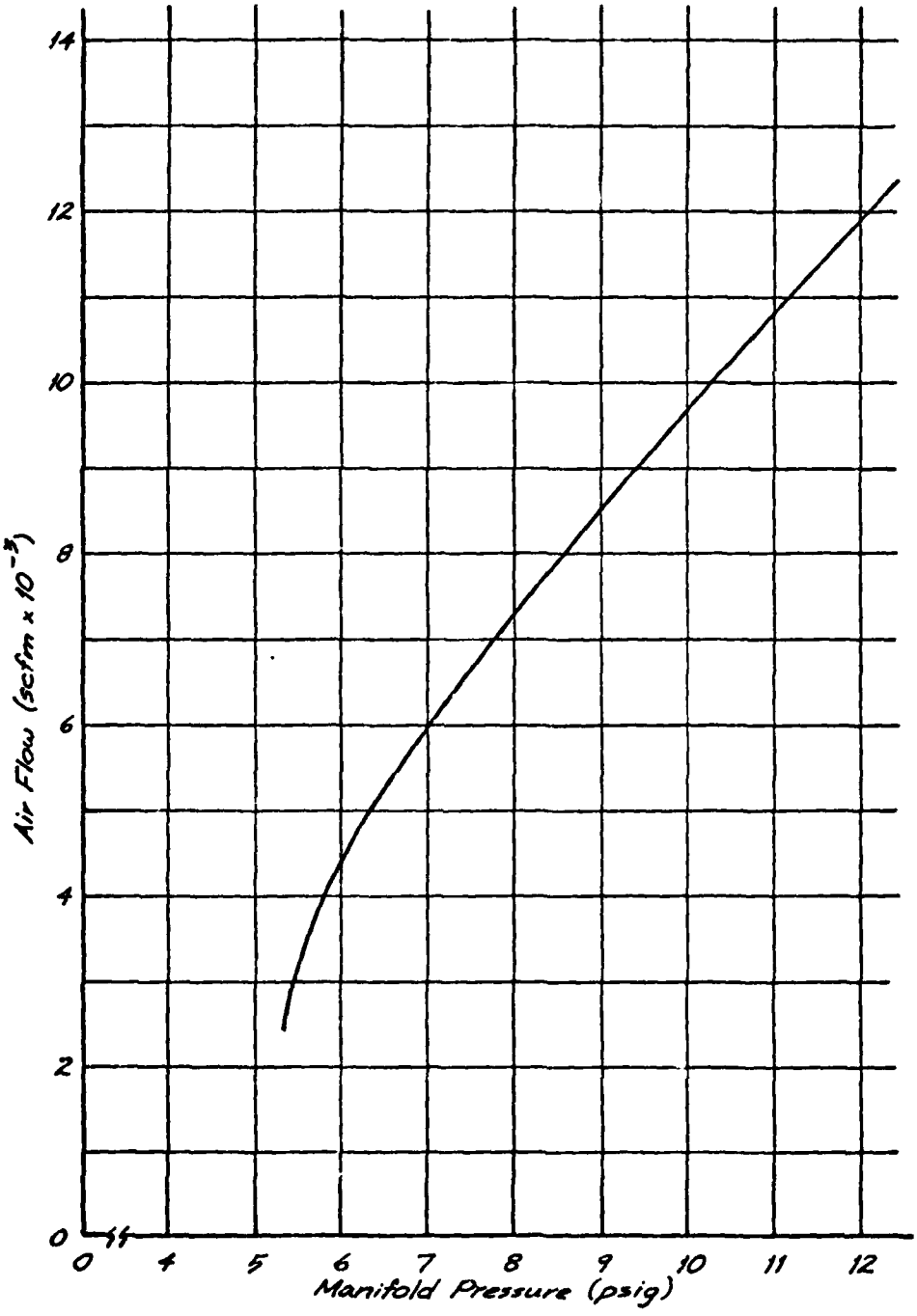

FIGURE 6
AIR FLOW CHARACTERISTIC WITH PORT OR STARBOARD MANIFOLDS

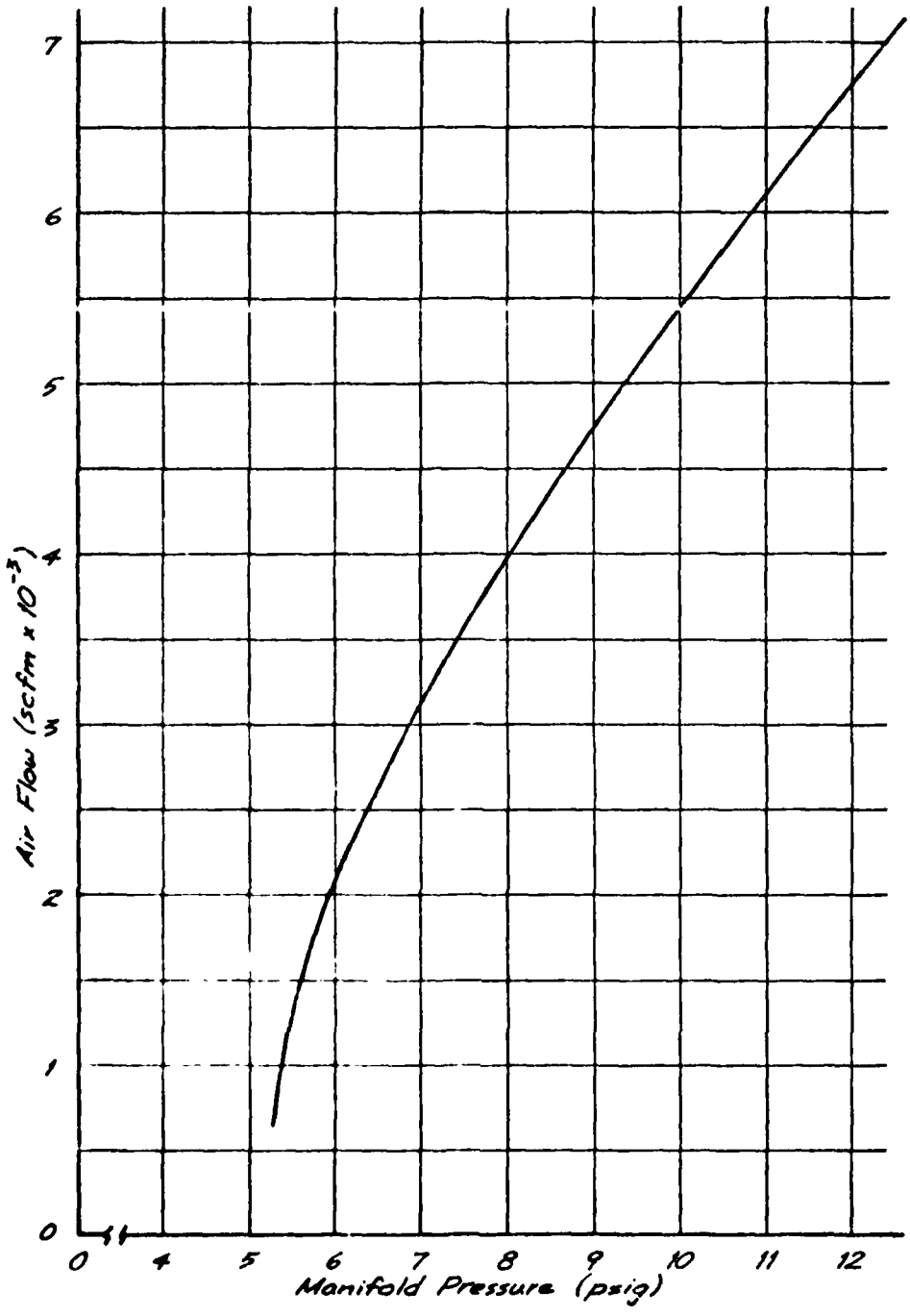

FIGURE 7
AIR FLOW CHARACTERISTIC OF ONE BOW MANIFOLD

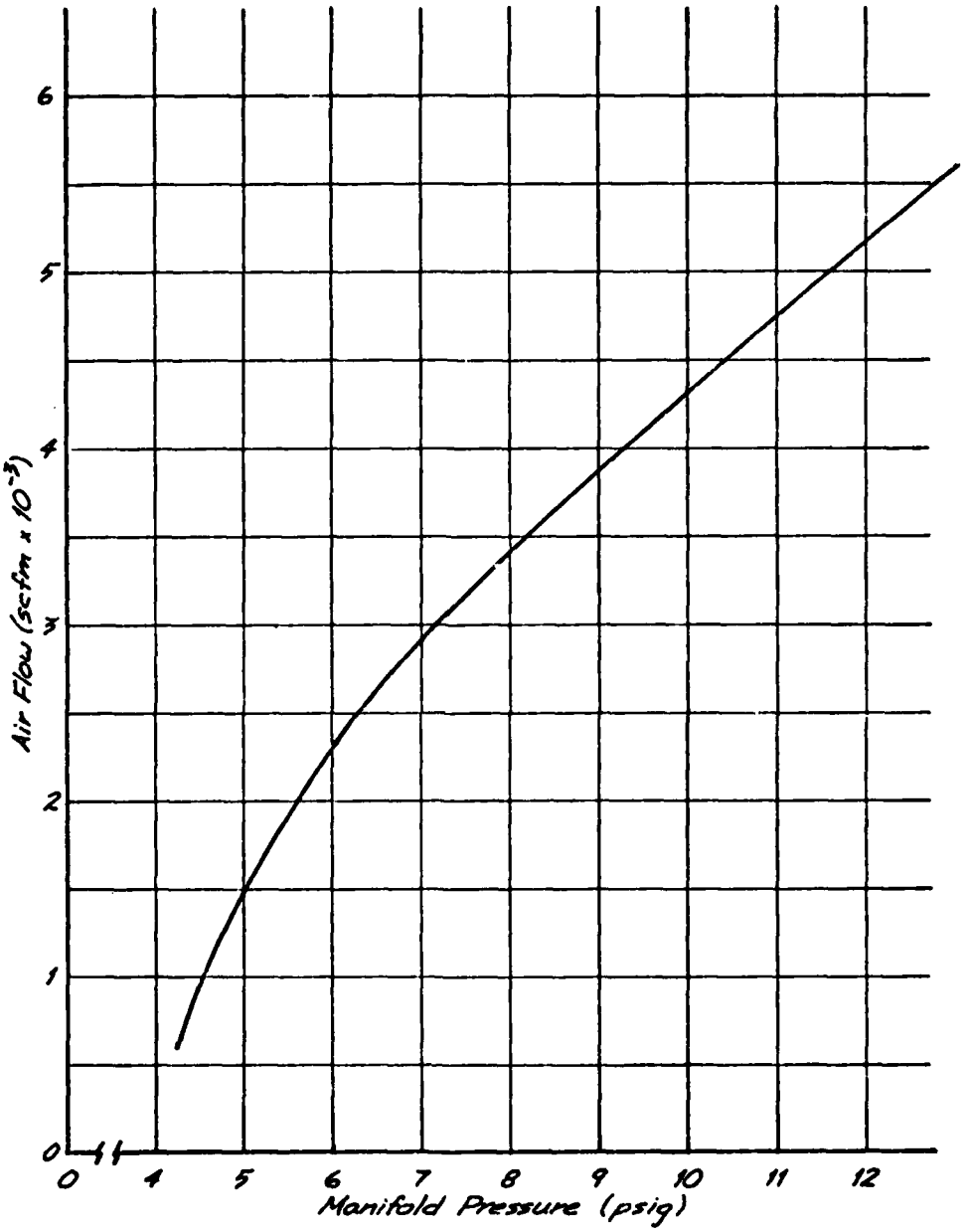

FIGURE 8
AIR FLOW CHARACTERISTIC OF ONE AFT MANIFOLD

III. DESIGN HISTORY

System Capacity

The only published data of operating experience with air bubbler systems has been from two experimental programs. The first was the U.S. Coast Guard testing program with the USCGC SUNDEW and the second was the MARAD testing program with the SS LEON FRASER (Reference 1). Neither program resulted in a specific criterion for establishing the capacity of a system; however, engineering judgement has led to a rule-of-thumb which sets the minimum capacity as one SCFS per foot of ship covered by the manifolds. The manifolds on the WYTM will extend for about 80 feet of the length of the ship. Using this rule-of-thumb, the minimum capacity would be approximately 5000 SCFM.

Other factors which must be considered are the operating pressure of the system, the capacity of air compressors available, and the ratings of diesel engines which are candidates as prime movers. Taking these factors into consideration and allowing a margin for test purposes, the system capacity was set at 7500 SCFM at 9 psig with a prime mover of 350 HP.

Size and Spacing of Orifices

The air flow rate, system pressure, and the size and spacing of the orifices are all interrelated. To solve this problem, two computer programs are available. The first determines the orifice diameter for a given flow rate, and the second calculates the flow rate for a manifold with given orifice diameters.

The programs are written utilizing three fundamental equations. The flow through an orifice is calculated using the following relationship:

$$q = C_D A_0 \sqrt{\frac{2}{\rho} \Delta P_0} \qquad (1)$$

The pressure at any point in the manifold is a function of friction losses and head gain due to reduced velocities in the manifold between orifices (References 2 and 3). The equation for friction loss is:

$$\Delta P \text{ friction} = f \frac{\rho l V_1^2}{2d} \qquad (2)$$

and the equation for the head increase due to deceleration is:

$$\Delta P \text{ deceleration} = \frac{\rho}{2} V_1^2 \left[2 \frac{q}{Q_1} - (1 + K) \times \left(\frac{q}{Q_1} \right)^2 \right] \quad (3)$$

Starting at the dead end of the manifold and working towards the supply end, the flow at each orifice is calculated knowing the pressure in the manifold at that orifice and the hydrostatic pressure outside the manifold at that orifice. Summing the flows from each orifice gives the total flow,and the pressure at the last orifice is the supply pressure.

Initial investigations for this design considered orifice spacing of 1, 2, 6, and 10 feet. The spacing on the SUNDEW was 12, 14-1/2, and 16 inches, depending on the manifold location. The spacing on the LEON FRASER was every 2 feet, and this spacing resulted in a very uniform distribution. Greater spacing on the WYTM was considered to reduce the number of orifices. Calculations for spacing of 4-1/2 feet and 6 feet were performed in the final design stages. The results of these calculations are in Appendix B. Orifice spacing of 6 feet was the final selection for the WYTM.

The manifold pressure is a function of the total orifice area. Small orifices with higher manifold pressures result in a very uniform flow distribution which is not very sensitive to changes in pressure; however, this requires more horsepower to achieve a given flow rate. In this design for the WYTM a large, total orifice area was utilized to keep the compressor power requirements within limits.

Piping System Design

For analysis of the pressure drop in the air piping system, the system was divided into the six sections listed in Table IV and indicated in Figure 1. Air flow calculations were performed for each mode of operation with the results tabulated in Tables V, VI, and VII. An absolute roughness of .005 feet for galvanized pipe was used in all of the calculations.

TABLE IV

AIR PIPING SYSTEM DESCRIPTION

Section No.	Description	I.D. (inches)	Length (feet)	Fittings	L/D
1	12" SCH 40	12.00	16	TEE (branch)	60
				ELL (LR)	20
2	10" SCH 40	10.02	30	TEE (branch)	60
				ELL (LR)	20
3	8" SCH 40	7.981	30	TEE (run)	20
				ELL (LR)	20
				ELL (LR)	20
4	8" SCH 80	7.625	15	45° ELL	16
				45° ELL	16
				Butterfly Valve	20
5	8" SCH 40	7.981	2	TEE (branch)	60
				ELL (LR)	
6	8" SCH 80	7.625	16	45° ELL	16
				45° ELL	16
				Butterfly Valve	20

TABLE V

PRESSURE DROP IN PIPING FOR MODE 1 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	7500	180	6	.28
2	3750	180	6	.18
3	1700	180	6	.10
4	1700	120	6	.08
5	2050	180	6	.10
6	2050	120	6	.11

TABLE VI

PRESSURE DROP IN PIPING FOR MODE 2 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	7500	180	9	.26
2	3750	180	9	.18
3	3750	180	9	.41
4	3750	120	8	.34

TABLE VII

PRESSURE DROP IN PIPING FOR MODE 3 AND 4 OPERATION

Section No.	Air Flow (SCFM)	Air Temp. (°F)	Pressure (psig)	ΔP (psig)
1	6750	180	9	.21
2	6750	180	9	.56
3	3550	180	9	.37
4	3550	120	9	.30
5	3200	180	9	.21
6	3200	120	8	.25

REFERENCES

1. Levine, G.H., Voelker, R.P., Mentz, P.B., "Advances in the Development of Commercial Ice-Transiting Ships," SNAME Transactions, Volume 82, 1974.

2. Keller, J.D., "The Manifold Problem," Journal of Applied Mechanics, March, 1949.

3. McNown, J.S., "Mechanics of Manifold Flow," Trans. ASCE, 1953.

APPENDIX A

TABLE A-1.

ALTERNATE FORWARD MANIFOLDS, PORT AND STARBOARD
4-1/2-FOOT ORIFICE SPACING

Orifice No.	Location (Frame No.)	Diameter (inches)
1	10 - 11	1.750
2	13 - 14	1.750
3	16 - 17	1.750
4	19 - 20	1.875
5	22 - 23	1.875
6	25 - 28	1.875
7	28 - 29	1.875

SUPPLY AT AFT END OF MANIFOLD.

TABLE A-2.

ALTERNATE AFT MANIFOLDS, PORT AND STARBOARD
4-1/2-FOOT ORIFICE SPACING

Orifice No.	Location (Frame No.)	Diameter (inches)
1	32 - 33	1.315
2	35 - 36	1.438
3	38 - 39	1.438
4	41 - 42	1.438
5	44 - 45	1.438
6	47 - 48	1.438
7	50 - 51	1.438
8	53 - 54	1.438
9	56 - 57	1.438
10	59 - 60	1.315

SUPPLY BETWEEN ORIFICES NO. 5 AND 6.

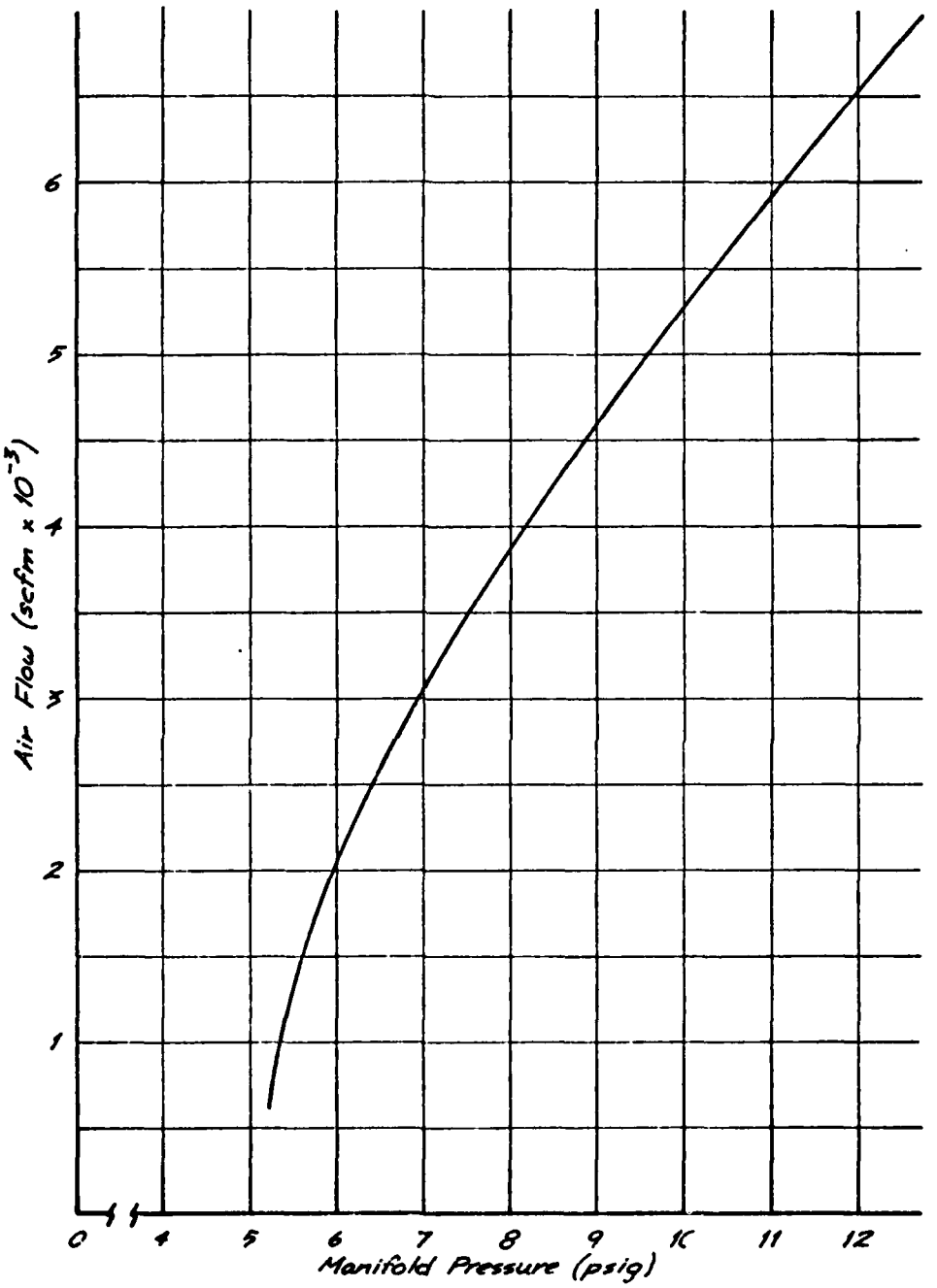

FIGURE A-1
ALTERNATE BOW MANIFOLD AIR FLOW CHARACTERISTIC

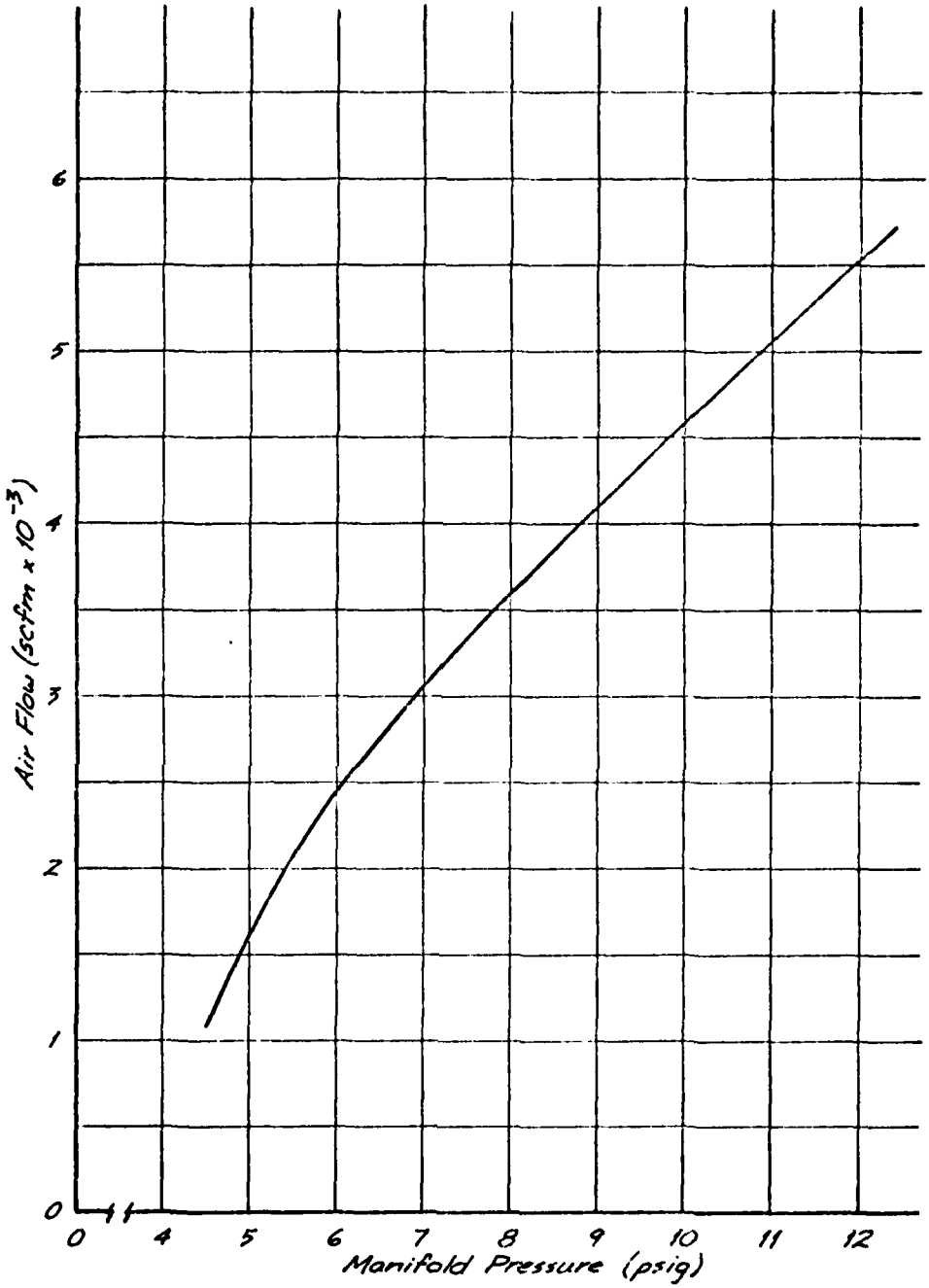

FIGURE A-2
ALTERNATE AFT MANIFOLD AIR FLOW CHARACTERISTIC

APPENDIX B

TABLE B-1 FORWARD MANIFOLD, 6-FOOT ORIFICE SPACING

CALCULATION OF MANIFOLD FLOW 3/ 5/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 6

NUMBER OF ORIFICES	6	
ORIFICE SPACING	6.0	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	30.0	FT
MANIFOLD AREA	15.0	30 IN
MANIFOLD HYDRAULIC DIA	8.7	IN
ROUGHNESS	0.00015	FT
AREA RATIO	1.860	
LENGTH/DIAMETER RATIO	97.3	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESS/FT OF WATER	0.433	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.875	11.8
2	1.875	11.8
3	2.000	11.8
4	2.000	11.9
5	2.125	12.0
6	2.125	12.0

TABLE B-1 (continued)

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

ORI NO.	V1 (FPS)	Q3 (CCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.52	2.1372	1.0000	5.284	5.113	0.00237	0.0334	0.4042 05
2	28.84	2.1068	0.9858	5.293	5.113	0.00239	0.0309	0.8058 05
3	44.78	2.3079	1.0799	5.265	5.113	0.00239	0.0297	0.1316 06
4	58.17	1.9756	0.9245	5.279	5.156	0.00239	0.0292	0.1716 06
5	70.17	1.7271	0.8082	5.276	5.200	0.00239	0.0288	0.1998 06
6	82.21	1.7714	0.8289	5.274	5.200	0.00239	0.0285	0.2192 06

TOTAL AIR FLOW 725.56 SCFM

ORI NO.	V1 (FPS)	Q3 (CCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	35.74	5.5205	1.0000	5.230	5.113	0.00236	0.0302	0.1042 06
2	70.99	5.4360	0.9851	5.257	5.113	0.00238	0.0287	0.2072 06
3	110.18	6.0277	1.0919	5.202	5.113	0.00234	0.0281	0.3217 06
4	147.57	5.7955	1.0499	5.144	5.156	0.00243	0.0277	0.4306 06
5	187.51	5.9113	1.0709	5.093	5.200	0.00243	0.0275	0.5466 06
6	226.53	5.9913	1.0854	5.047	5.200	0.00242	0.0274	0.6602 06

TOTAL AIR FLOW 2027.29 SCFM

TABLE B-1 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	47.40	7.6687	1.0000	7.283	5.113	0.00362	0.0194	0.145E 06
2	94.20	7.5491	0.9844	7.221	5.113	0.00361	0.0182	0.287E 06
3	146.25	8.3569	1.0897	7.118	5.113	0.00359	0.0177	0.444E 06
4	196.40	8.0124	1.0448	7.009	5.156	0.00358	0.0174	0.593E 06
5	250.58	8.6074	1.1224	6.887	5.200	0.00356	0.0173	0.758E 06
6	303.47	8.3692	1.0913	6.801	5.200	0.00354	0.0172	0.908E 06

TOTAL AIR FLOW 2913.82 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	55.98	9.4640	1.0000	8.275	5.113	0.00378	0.0190	0.179E 06
2	111.27	9.3105	0.9838	8.185	5.113	0.00377	0.0179	0.354E 06
3	172.81	10.2961	1.0879	8.034	5.113	0.00375	0.0175	0.547E 06
4	232.37	9.8935	1.0454	7.873	5.156	0.00372	0.0173	0.730E 06
5	297.01	10.6512	1.1254	7.691	5.200	0.00369	0.0172	0.926E 06
6	360.13	10.3399	1.0924	7.560	5.200	0.00367	0.0171	0.112E 07

TOTAL AIR FLOW 3597.26 SCFM

TABLE B-1 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	68.82	11.0793	1.0000	9.267	5.113	0.00395	0.0137	0.210E 06
2	124.90	10.8498	0.9800	9.149	5.113	0.00393	0.0178	0.415E 06
3	194.06	12.0535	1.0883	8.958	5.113	0.00390	0.0174	0.607E 06
4	261.17	11.5738	1.0448	8.737	5.156	0.00396	0.0172	0.852E 06
5	334.21	12.4388	1.1232	8.494	5.200	0.00382	0.0171	0.108E 07
6	405.56	12.0993	1.0919	8.314	5.200	0.00379	0.0170	0.130E 07

TOTAL AIR FLOW 4208.04 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	68.52	12.5841	1.0000	10.259	5.113	0.00411	0.0135	0.209E 06
2	136.26	12.3673	0.9828	10.113	5.113	0.00409	0.0176	0.470E 06
3	211.79	13.6518	1.0849	9.864	5.113	0.00405	0.0173	0.729E 06
4	285.21	13.1691	1.0465	9.601	5.156	0.00400	0.0171	0.983E 06
5	365.31	14.1496	1.1243	9.268	5.200	0.00395	0.0170	0.126E 07
6	443.58	13.9518	1.1086	9.077	5.200	0.00392	0.0170	0.147E 07

TOTAL AIR FLOW 4774.16 SCFM

TABLE B-1 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	73.39	14.0140	1.0000	11.252	5.113	0.00427	0.0183	0.265E 06
2	145.98	13.7663	0.9823	11.076	5.113	0.00425	0.0175	0.524E 06
3	226.97	15.1844	1.0835	10.782	5.113	0.00420	0.0172	0.805E 06
4	305.83	14.6009	1.0419	10.465	5.156	0.00415	0.0171	0.107E 07
5	391.99	15.7836	1.1220	10.101	5.200	0.00409	0.0170	0.135E 07
6	476.24	15.2101	1.0854	9.835	5.200	0.00404	0.0169	0.163E 07

TOTAL AIR FLOW 5309.95 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	77.64	15.3899	1.0000	12.244	5.113	0.00444	0.0182	0.291E 06
2	154.45	15.1116	0.9819	12.040	5.113	0.00440	0.0175	0.575E 06
3	240.21	16.6563	1.0823	11.[illegible]	5.113	0.00435	0.0172	0.882E 06
4	323.82	16.0119	1.0404	11.[illegible]	5.156	0.00429	0.0170	0.117E 07
5	415.32	17.2373	1.1200	10.[illegible]	5.200	0.00422	0.0170	0.148E 07
6	504.83	16.6578	1.0824	10.[illegible]	5.200	0.00417	0.0169	0.178E 07

TOTAL AIR FLOW 5823.89 SCFM

TABLE B-1 (continued)

DPI NO.	V1 (FPS)	Q3 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	81.38	16.7251	1.0000	13.226	5.113	0.00461	0.0131	0.316E 06
2	151.92	16.4163	0.9815	13.094	5.113	0.00456	0.0174	0.594E 06
3	251.90	16.0814	1.0211	12.814	5.113	0.00450	0.0171	0.917E 06
4	339.73	17.3779	1.0396	12.192	5.156	0.00443	0.0170	0.127E 07
5	435.96	18.4978	1.1179	11.708	5.200	0.00455	0.0139	0.145E 07
6	530.16	18.0543	1.0795	11.351	5.200	0.00459	0.0139	0.172E 07

TOTAL AIR FLOW 6321.12 SCFM

TABLE B-2 AFT MANIFOLD, 6-FOOT ORIFICE SPACING, ORIFICES NO. 1-4

CALCULATION OF MANIFOLD FLOW 3/ 6/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 4

NUMBER OF ORIFICES	4	
ORIFICE SPACING	6.0	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	18.0	FT
MANIFOLD AREA	37.7	SQ IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.196	
LENGTH/DIAMETER RATIO	37.2	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESS/FT OF WATER	0.433	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.438	8.8
2	1.562	9.3
3	1.562	9.6
4	1.562	9.8

TABLE B-2 (continued)

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	5.90	2.0604	1.0000	4.345	3.813	0.00314	0.0254	0.3455E 05
2	11.27	1.8910	0.9090	4.343	4.056	0.00314	0.0222	0.4608E 05
3	15.38	1.4473	0.6957	4.245	4.160	0.00314	0.0210	0.5398E 05
4	18.37	1.0530	0.5061	4.344	4.245	0.00314	0.0204	0.7638E 05

TOTAL AIR FLOW 386.30 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	9.76	3.4190	1.0000	5.346	3.813	0.00350	0.0226	0.4827E 05
2	20.47	3.4344	1.0045	5.343	4.056	0.00350	0.0194	0.6993E 05
3	30.54	3.7482	1.0960	5.339	4.160	0.00350	0.0187	0.1034E 06
4	40.25	3.5952	0.9948	5.334	4.245	0.00350	0.0181	0.1758E 06

TOTAL AIR FLOW 895.31 SCFM

TABLE B-2 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	12.24	4.7649	1.0000	6.345	3.813	0.00347	0.0215	0.562E 05
2	26.06	5.3769	1.1285	6.340	4.030	0.00347	0.0190	0.120E 06
3	39.46	5.2131	1.0941	6.333	4.160	0.00347	0.0180	0.181E 06
4	52.56	5.0954	1.0694	6.323	4.246	0.00346	0.0174	0.241E 06

TOTAL AIR FLOW 1227.01 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.12	5.7592	1.0000	7.345	3.813	0.00363	0.0209	0.679E 05
2	30.28	6.5842	1.1433	7.338	4.030	0.00363	0.0185	0.146E 06
3	46.02	6.4404	1.1183	7.326	4.160	0.00363	0.0176	0.221E 06
4	61.65	6.3351	1.1000	7.312	4.246	0.00363	0.0171	0.296E 06

TOTAL AIR FLOW 1507.13 SCFM

TABLE B-2 (continued)

COMP NO.	W1 (SCFM)	P3 (PSIA)	P2 (NORMAL	P1 (PSIA)	P3 (PSIA)	AIR FLOW (CU.FT/SEC)	F FACT	REV NO.
1	15.65	[illegible]	1.0000	[illegible]	3.813	[illegible]	0.3503	[illegible]
2	33.57	[illegible]	1.1514	[illegible]	4.120	[illegible]	[illegible]	[illegible]
3	51.41	[illegible]	1.1515	[illegible]	4.120	[illegible]	[illegible]	[illegible]
4	69.41	[illegible]	1.1167	[illegible]	4.[illegible]	[illegible]	[illegible]	[illegible]

TOTAL AIR FLOW 170.50 SCFM

COMP NO.	W1 (SCFM)	P3 (PSIA)	P2 NORMAL	P1 (PSIA)	P3 (PSIA)	AIR FLOW (CU.FT/SEC)	F FACT	REV NO.
1	15.53	[illegible]	1.0000	0.144	3.813	[illegible]	0.0136	[illegible]
2	34.01	[illegible]	1.1526	4.259	4.120	[illegible]	[illegible]	[illegible]
3	52.00	[illegible]	1.1524	4.314	4.120	[illegible]	[illegible]	[illegible]
4	70.45	[illegible]	1.1571	4.281	[illegible]	[illegible]	[illegible]	[illegible]

TOTAL AIR FLOW [illegible] SCFM

TABLE B-2 (continued)

ORI NO.	V1 (FPS)	Q3 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	18.02	8.3463	1.0000	10.344	3.813	0.00413	0.0196	0.9745 05
2	38.84	9.6831	1.1602	10.330	4.030	0.00412	0.0177	0.2138 06
3	59.62	9.9614	1.1456	10.308	4.160	0.00411	0.0169	0.3693 06
4	80.11	9.4666	1.1342	10.280	4.246	0.00411	0.0165	0.4978 06

TOTAL AIR FLOW 2223.45 SCFM

ORI NO.	V1 (FPS)	Q3 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	18.48	9.1392	1.0000	11.343	3.813	0.00429	0.0193	0.1185 06
2	41.06	10.6868	1.1688	11.328	4.030	0.00429	0.0175	0.2329 06
3	63.91	10.9078	1.1497	11.302	4.160	0.00429	0.0168	0.3537E 06
4	84.59	10.4133	1.1394	11.270	4.246	0.00428	0.0164	0.4790 06

TOTAL AIR FLOW 2441.20 SCFM

TABLE B-2 (continued)

DPI NO.	V1 (FPS)	Q2 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	19.98	9.9116	1.0000	13.34	3.813	0.00445	0.019	0.117E 06
2	42.92	11.5446	1.1648	13.12	4.030	0.00445	0.0173	0.253E 06
3	65.91	11.4078	1.1509	12.99	4.146	0.00445	0.016	0.389E 06
4	88.55	11.3757	1.1477	12.96	4.175	0.00444	0.015	0.521E 06

TOTAL AIR FLOW 2852.93 SCFM

DPI NO.	V1 (FPS)	Q2 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	20.57	10.2079	1.0299	13.342	3.813	0.00442	0.0194	0.124E 06
2	44.59	12.4428	1.1663	13.362	4.030	0.00442	0.0172	0.273E 06
3	68.40	12.2854	1.1514	13.350	4.146	0.00441	0.0164	0.418E 06
4	92.07	12.2529	1.1484	13.348	4.246	0.00441	0.0152	0.561E 06

TOTAL AIR FLOW 2859.91 SCFM

TABLE B-3 AFT MANIFOLD, 6-FOOT ORIFICE SPACING, ORIFICES NO. 5-8

CALCULATION OF MANIFOLD FLOW 3/ 5/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 4

NUMBER OF ORIFICES	4	
ORIFICE SPACING	6.0	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	18.0	FT
MANIFOLD AREA	37.7	SQ IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.196	
LENGTH DIAMETER RATIO	37.2	
K	0.499	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
WEIGHT OF WATER	0.433	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.438	8.9
2	1.542	9.5
3	1.582	9.8
4	1.562	9.9

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

TABLE B-3 (continued)

DFI NO.	V1 (FPS)	Q2 (CCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	5.90	2.0887	1.0000	4.399	3.856	0.00315	0.0254	0.2485 05
2	10.88	1.7506	0.8444	4.399	4.116	0.00317	0.0234	0.4332 05
3	14.47	1.2690	0.6093	4.366	4.245	0.00315	0.0212	0.5038 05
4	17.46	1.0553	0.5067	4.388	4.299	0.00315	0.0205	0.727E 05

TOTAL AIR FLOW 369.94 CCFM

DFI NO.	V1 (FPS)	Q2 (CCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	9.75	3.5219	1.0000	5.389	3.856	0.00331	0.0236	0.427E 05
2	20.23	3.0946	1.0754	5.21	4.116	0.00[illegible]	0.0195	0.8[illegible]E 05
3	30.14	2.5233	1.0169	5.082	4.245	[illegible]	0.0187	0.[illegible]E 06
4	39.85	2.0134	0.9449	5.277	4.299	0.00331	0.0181	0.1[illegible]E 06

TOTAL AIR FLOW 889.19 CCFM

TABLE B-3 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	12.23	4.7698	1.0000	6.388	3.856	0.00347	0.0215	0.563E 05
2	25.90	5.3818	1.1178	6.384	4.116	0.00347	0.0190	0.119E 06
3	39.15	5.1665	1.0832	6.375	4.246	0.00347	0.0180	0.180E 06
4	52.24	5.1009	1.0694	6.367	4.290	0.00347	0.0174	0.240E 06

TOTAL AIR FLOW 1222.14 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.11	5.7648	1.0000	7.388	3.856	0.00364	0.0208	0.680E 05
2	30.14	6.5474	1.1358	7.381	4.116	0.00364	0.0185	0.145E 06
3	45.83	6.4027	1.1106	7.370	4.246	0.00364	0.0176	0.221E 06
4	61.37	6.3416	1.1001	7.356	4.290	0.00363	0.0171	0.295E 06

TOTAL AIR FLOW 1503.39 SCFM

TABLE B-3 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LBM/FT3)	F FACT	REY NO.
1	15.63	6.6758	1.0000	8.398	3.854	0.0[illegible]	0.0213	0.787E [illegible]
2	33.55	7.6479	1.1456	8.379	4.116	0.[illegible]	0.0171	0.1[illegible]E [illegible]
3	51.17	7.5146	1.1257	8.364	4.246	0.00[illegible]	0.0173	0.[illegible]E [illegible]
4	68.56	7.4549	1.1167	8.345	4.298	0.00[illegible]	0.0169	0.[illegible]E [illegible]

TOTAL AIR FLOW 1757.58 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LBM/FT3)	F FACT	REY NO.
1	16.91	7.5832	1.0000	9.887	3.856	0.00397	0.0193	0.9895 05
2	36.40	8.6772	1.1519	9.[illegible]	4.11[illegible]	0.00397	0.0174	0.191[illegible] 06
3	55.42	8.5508	1.1351	9.[illegible]	4.246	0.00396	0.0171	0.293E 06
4	74.72	8.4909	1.1271	9.[illegible]	4.298	0.00394	0.0167	0.[illegible]E 06

TOTAL AIR FLOW 1999.12 SCFM

TABLE B-3 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	18.01	8.3535	1.0000	10.387	3.856	0.00413	0.0196	0.885E 05
2	38.84	9.6581	1.1562	10.374	4.116	0.00413	0.0177	0.212E 06
3	59.42	9.5361	1.1416	10.352	4.246	0.00413	0.0169	0.325E 06
4	79.89	9.4751	1.1343	10.324	4.290	0.00412	0.0165	0.436E 06

TOTAL AIR FLOW 2221.37 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	18.96	9.1468	1.0000	11.385	3.856	0.00430	0.0193	0.108E 06
2	40.96	10.6041	1.1593	11.371	4.116	0.00429	0.0175	0.233E 06
3	62.73	10.4848	1.1463	11.346	4.246	0.00429	0.0168	0.356E 06
4	84.39	10.4222	1.1394	11.313	4.290	0.00429	0.0164	0.479E 06

TOTAL AIR FLOW 2439.47 SCFM

TABLE B-3 (continued)

OPI NO.	V1 (FPS)	Q2 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FRIT	REY NO.
1	19.81	9.9195			3.856	0.00445	0.0191	0.117E 06
2	43.83	11.5453			4.116	0.00415	0.0172	0.233E 06
3	55.64	11.4060	1.1453	14.383	4.245	0.00415	0.0157	0.387E 06
4	56.36	11.3414	1.1453	12.302	4.290	0.00445	0.0153	0.520E 06

TOTAL AIR FLOW 2651.44 SCFM

OPI NO.	V1 (FPS)	Q2 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FRIT	REY NO.
1	20.56	10.6762	1.0010	13.394	3.856	0.00453	0.0189	0.126E 06
2	45.50	12.4899	1.1636	13.964	4.116	0.00430	0.0172	0.275E 06
3	57.24	12.3054	1.1587	14.338	4.245	0.00430	0.0156	0.416E 06
4	57.98	12.2391	1.1464	14.792	4.290	0.00461	0.0152	0.561E 06

TOTAL AIR FLOW 2858.14 SCFM

TABLE B-4 ALTERNATE FORWARD MANIFOLD, 4½-FOOT ORIFICE SPACING

CALCULATION OF MANIFOLD FLOW 3/ 6/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 7

NUMBER OF ORIFICES	7	
ORIFICE SPACING	4.5	FT
DISCHARGE COEFFICIENT	0.820	
MANIFOLD LENGTH	27.0	FT
MANIFOLD AREA	15.0	SQ IN
MANIFOLD HYDRAULIC DIA	3.7	IN
ROUGHNESS	0.00015	FT
AREA RATIO	1.217	
LENGTH/DIAMETER RATIO	87.6	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESS/FT OF WATER	0.433	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.750	11.8
2	1.750	11.8
3	1.750	11.8
4	1.875	11.9
5	1.875	11.9
6	1.875	12.0
7	1.875	12.0

TABLE B-4 (continued)

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	12.66	1.8635	1.0000	5.298	5.113	0.00230	0.0240	0.352E 05
2	65.18	1.8435	0.9887	5.294	5.113	0.00385	0.0213	0.701E 05
3	37.49	1.8114	0.9710	5.289	5.113	0.00259	0.0202	0.104E 06
4	46.47	1.7609	0.9449	5.282	5.156	0.00329	0.0185	0.138E 06
5	51.14	1.7169	0.9213	5.276	5.156	0.00359	0.0191	0.170E 06
6	70.38	1.6773	0.7364	5.274	5.200	0.00499	0.0183	0.195E 06
7	73.62	1.3986	0.7290	5.274	5.200	0.00529	0.0184	0.221E 06

TOTAL AIR FLOW 700.65 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	31.16	4.8138	1.0000	6.293	5.113	0.00246	0.0205	3.910E 05
2	61.98	4.7508	0.9879	6.286	5.113	0.00	0.0193	7.191E 05
3	92.31	4.6716	0.9715	6.277	5.113	0.00	0.0182	1.063E 06
4	125.42	5.1164	1.0639	6.173	5.156	0.00	0.0179	1.365E 06
5	156.05	4.9744	1.0343	6.118	5.156	0.00	0.0177	1.665E 06
6	188.97	4.7459	0.9867	6.078	5.200	0.00	0.0172	1.954E 06
7	214.09	4.6246	0.9615	6.077	5.200	0.00	0.0172	2.25 E 06

TOTAL AIR FLOW 2020.91 SCFM

TABLE B-4 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	41.33	6.6873	1.0000	7.387	5.113	0. [illegible]	0.0197	0.1868 06
2	82.24	6.6045	0.9876	7.2[illegible]	[illegible]	[illegible]	0.0184	0.3515 06
3	123.51	6.4806	0.9691	7.156	5.113	0. [illegible]	0.0179	0.5065 06
4	157.18	7.1546	1.0699	7.[illegible]	5.156	0.[illegible]	0.0175	0.5965 06
5	210.71	6.9371	1.0374	6.9[illegible]	5.[illegible]	0.[illegible]	0.0174	0.[illegible] 06
6	252.66	6.6592	0.9957	6.8[illegible]	5.20[illegible]	0.[illegible]	0.0173	0.1586 06
7	293.79	6.5070	0.9730	6.797	5.200	0.[illegible]	0.0172	0.[illegible]E 06

TOTAL AIR FLOW 2821.76 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	48.80	8.2531	1.0000	8.261	5.113	0.00[illegible]	0.0192	0.156E 06
2	97.13	8.1471	0.9872	8.209	5.113	0.00[illegible]	0.0181	0.310E 06
3	144.74	7.9884	0.9679	8.1[illegible]	5.113	0.00[illegible]	0.0177	0.4595 06
4	197.76	8.8398	1.0711	7.953	5.156	0.00[illegible]	0.0174	0.6232 06
5	244.47	8.5609	1.0373	7.798	5.156	0.00[illegible]	0.0173	0.7715 06
6	299.53	8.2881	0.9988	7.661	5.200	0.00[illegible]	0.0172	0.9535 06
7	348.68	8.0402	0.9742	7.556	5.240	0.00[illegible]	0.0171	0.1[illegible]E 07

TOTAL AIR FLOW 3484.05 SCFM

TABLE B-4 (continued)

CPI NO.	V1 (FPS)	Q2 (SCFS)	DO NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	54.77	5.6520	1.0000	9.205	5.113	0.00399	0.0186	0.181E 06
2	104.82	9.5038	0.9867	9.181	5.113	0.00393	0.0179	0.345E 06
3	142.50	9.3421	0.9659	9.042	5.113	0.00381	0.0175	0.430E 06
4	242.22	10.[illegible]	1.0709	8.543	5.156	0.00353	0.0171	0.[illegible] 06
5	200.51	10.[illegible]	1.0[illegible]	8.[illegible]	5.156	0.00[illegible]	0.0172	0.[illegible] 06
6	187.09	9.8213	0.9478	9.405	5.200	0.00381	0.0174	0.[illegible] 06
7	342.59	9.3998	0.9728	8.314	5.200	0.00379	0.0171	0.[illegible] 06

TOTAL AIR FLOW [illegible] SCFS

CPI NO.	V1 (FPS)	Q2 (SCFS)	DO NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	58.74	10.[illegible]	1.0000	10.269	5.113	0.00411	0.0187	0.200E 06
2	1[illegible].93	10.[illegible]	0.98[illegible]	10.153	5.113	0.00408	0.0175	0.411E 06
3	177.31	10.[illegible]	0.9[illegible]	9.980	5.113	0.00[illegible]	0.0174	0.[illegible]E 06
4	2[illegible].53	11.[illegible]	1.0700	9.793	5.156	0.00[illegible]	0.0172	0.[illegible]E 06
5	[illegible].42	11.[illegible]	1.0[illegible]	9.[illegible]	5.156	0.00[illegible]	0.0171	0.[illegible] 06
6	[illegible].42	[illegible].[illegible]	0.[illegible]	9.[illegible]	5.[illegible]	0.00[illegible]	0.0170	0.[illegible] 06
7	[illegible].37	1[illegible].[illegible]	0.[illegible]	9.[illegible]	5.[illegible]	0.00[illegible]	0.0170	0.[illegible] 06

TOTAL AIR FLOW [illegible] SCFS

TABLE B-4 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	63.98	12.2220	1.0000	11.263	5.113	0.00428	0.0185	0.231E 06
2	127.41	12.0306	0.9860	11.124	5.113	0.00425	0.0177	0.458E 06
3	189.98	11.7951	0.9651	10.918	5.113	0.00422	0.0173	0.677E 06
4	260.10	13.0641	1.0689	10.623	5.156	0.00417	0.0172	0.917E 06
5	328.64	12.6175	1.0324	10.318	5.156	0.00418	0.0171	0.114E 07
6	395.41	12.1558	0.9946	10.044	5.200	0.00408	0.0170	0.136E 07
7	460.56	11.8309	0.9680	9.829	5.200	0.00404	0.0169	0.157E 07

TOTAL AIR FLOW 5144.16 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSID)	P3 (PSID)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	67.68	13.4823	1.0000	12.257	5.113	0.00444	0.0184	0.254E 06
2	134.78	13.2299	0.9857	12.096	5.113	0.00441	0.0176	0.503E 06
3	201.03	12.9427	0.9643	11.856	5.113	0.00437	0.0173	0.748E 06
4	275.34	14.0324	1.0478	11.513	5.156	0.00432	0.0171	0.100E 07
5	348.05	13.6217	1.0305	11.158	5.156	0.00426	0.0170	0.125E 07
6	418.95	13.2730	0.9926	10.898	5.200	0.00421	0.0170	0.149E 07
7	488.60	12.9573	0.9654	10.506	5.200	0.00417	0.0169	0.172E 07

TOTAL AIR FLOW 5642.36 SCFM

TABLE B-4 (continued)

DBI NO.	W1 (FPS)	Q3 (CFS)	JM MOMENTUM	P1 (PSIA)	P3 (PSIA)	PIP DEN (SLUG/FT3)	F FACT	REY NO.
1	79.94	14.9472	1.0000	13.251	5.113	0.00460	0.0183	0.2745 06
2	141.30	14.9798	0.9854	13.147	5.113	0.00457	0.0175	0.5355 06
3	310.79	14.9573	0.9435	12.794	5.113	0.00453	0.0172	0.1[illegible] 07
4	496.82	15.9469	1.0567	12.483	5.156	0.00446	0.0171	0.1058 07
5	485.21	15.0957	1.0097	11.999	5.156	0.00438	0.0170	0.1[illegible] 07
6	475.90	14.4159	1.0096	11.618	5.230	0.00434	0.0169	0.1618 07
7	513.10	14.9449	0.9688	11.349	5.300	0.00429	0.0169	0.1[illegible] 07

TOTAL AIR FLOW 6184.60 SCFM

TABLE B-5 ALTERNATE AFT MANIFOLD, 4½-FOOT ORIFICE SPACING, ORIFICES NO. 1-5

CALCULATION OF MANIFOLD FLOW 3/ 6/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 5

NUMBER OF ORIFICES	5	
ORIFICE SPACING	4.5	FT
DISCHARGE COEFFICIENT	0.820	
MANIFOLD LENGTH	18.0	FT
MANIFOLD AREA	37.7	30 IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.208	
LENGTH/DIAMETER RATIO	37.8	
K	0.400	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PSI/FT OF WATER	0.433	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.915	8.7
2	1.438	9.2
3	1.438	9.5
4	1.438	9.7
5	1.438	9.8

TABLE B-5 (continued)

LOCATION 1 IS IN MANIFOLD [illegible] ORIFICE
LOCATION 2 IS IN MANIFOLD [illegible] OF [illegible] ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

ORI NO.	V1 (FPS)	Q2 (CFM)	C3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUGS/FT)	E RATIO	REY NO.
1	5.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	9.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	13.85	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	16.89	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	19.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TOTAL AIR FLOW 411.37 CFM

ORI NO.	V1 (FPS)	Q2 (CFM)	C3 NORMAL	P1 (PSI)	P2 (PSI)	AIR DEN (SLUGS/FT)	E RATIO	REY NO.
1	8.28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	17.45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	26.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	34.56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	42.79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TOTAL AIR FLOW 951.72 CFM

TABLE B-5 (continued)

GPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	10.33	4.0216	1.0000	6.346	3.770	0.00347	0.0222	0.474E 05
2	22.14	4.5952	1.1426	6.342	3.986	0.00347	0.0195	0.102E 06
3	33.50	4.4600	1.1089	6.336	4.116	0.00347	0.0184	0.154E 06
4	44.82	4.3634	1.0850	6.328	4.203	0.00346	0.0177	0.206E 06
5	55.90	4.3086	1.0714	6.319	4.245	0.00346	0.0173	0.256E 06

TOTAL AIR FLOW 1304.93 SCFM

GPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	11.89	4.8492	1.0000	7.345	3.770	0.00363	0.0214	0.572E 05
2	25.66	5.6115	1.1572	7.340	3.986	0.00363	0.0189	0.123E 06
3	34.14	5.4932	1.1328	7.331	4.116	0.00363	0.0179	0.188E 06
4	52.42	5.4076	1.1151	7.320	4.203	0.00363	0.0173	0.252E 06
5	65.59	5.3568	1.1047	7.307	4.245	0.00363	0.0170	0.315E 06

TOTAL AIR FLOW 1603.09 SCFM

TABLE B-5 (continued)

DRI NO.	V1 (FPS)	Q3 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	13.18	5.6089	1.0000	9.345	8.770	0.00290	0.0205	0.5A2E 05
2	28.50	6.5352	1.1653	9.038	8.998	0.00380	0.0195	0.1A3E 06
3	43.59	6.4867	1.1459	8.797	4.116	0.00379	0.0175	0.2195 06
4	58.50	6.3467	1.1217	8.518	4.208	0.00379	0.0171	0.2945 06
5	75.31	6.8573	1.1229	8.298	4.245	0.00379	0.0167	0.3A45 06

TOTAL AIR FLOW 1878.85 SCFM

DRI NO.	V1 (FPS)	Q3 (CFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.22	6.7334	1.0000	9.345	8.770	0.00295	0.0203	0.74EE 05
2	30.87	7.4411	1.1704	9.036	8.956	0.00348	0.0182	0.16EE 06
3	47.29	7.2988	1.1542	8.7[illegible]	4.116	0.00375	0.0174	0.24EE 06
4	63.57	7.6220	1.1421	8.504	4.208	0.00375	0.0168	0.33EE 06
5	79.74	7.1778	1.1349	8.288	4.245	0.00375	0.0164	0.41EE 06

TOTAL AIR FLOW 2129.07 SCFM

TABLE B-5 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	15.13	7.0081	1.0000	10.344	3.770	0.00413	0.0201	0.827E 05
2	32.90	8.2275	1.1740	10.335	3.986	0.00412	0.0180	0.180E 06
3	50.47	8.1293	1.1600	10.318	4.116	0.00412	0.0172	0.275E 06
4	67.90	8.0542	1.1493	10.296	4.203	0.00412	0.0167	0.370E 06
5	85.23	8.0042	1.1421	10.270	4.246	0.00411	0.0164	0.464E 06

TOTAL AIR FLOW 2365.40 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	15.93	7.6705	1.0000	11.344	3.770	0.00425	0.0198	0.905E 05
2	34.68	9.0353	1.1766	11.333	3.986	0.00429	0.0178	0.197E 06
3	53.24	8.9098	1.1642	11.313	4.116	0.00428	0.0170	0.302E 06
4	71.67	8.8556	1.1545	11.288	4.203	0.00428	0.0166	0.406E 06
5	90.01	8.8043	1.1478	11.258	4.246	0.00428	0.0163	0.510E 06

TOTPL AIR FLOW 2597.13 SCFM

TABLE B-5 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	16.63	8.2160	1.0000	12.344	3.770	0.00445	0.0196	0.981E 05
2	36.24	9.8013	1.1786	12.331	3.986	0.00445	0.0177	0.214E 06
3	55.68	9.7078	1.1674	12.309	4.116	0.00445	0.0169	0.328E 06
4	74.99	9.6337	1.1585	12.280	4.203	0.00444	0.0165	0.441E 06
5	94.22	9.5810	1.1521	12.245	4.246	0.00444	0.0162	0.554E 06

TOTAL AIR FLOW 2822.39 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	17.26	8.9483	1.0000	13.343	3.770	0.00462	0.0194	0.106E 06
2	37.63	10.5605	1.1802	13.329	3.986	0.00462	0.0175	0.230E 06
3	57.85	10.4682	1.1699	13.304	4.116	0.00461	0.0168	0.353E 06
4	77.95	10.3939	1.1616	13.272	4.203	0.00461	0.0164	0.476E 06
5	97.96	10.3345	1.1555	13.233	4.246	0.00460	0.0162	0.597E 06

TOTAL AIR FLOW 3042.62 SCFM

TABLE B-6 ALTERNATE AFT MANIFOLD, 4½-FOOT ORIFICE SPACING, ORIFICES NO. 6-10

CALCULATION OF MANIFOLD FLOW 8/ 6/75

SPECIFIED ORIFICE DIAMETERS

SUPPLY AT ORIFICE 5

NUMBER OF ORIFICES	5	
ORIFICE SPACING	4.5	FT
DISCHARGE COEFFICIENT	0.620	
MANIFOLD LENGTH	18.0	FT
MANIFOLD AREA	27.7	30 IN
MANIFOLD HYDRAULIC DIA	5.8	IN
ROUGHNESS	0.00015	FT
AREA RATIO	0.208	
LENGTH/DIAMETER RATIO	37.2	
K	0.410	
AIR TEMPERATURE	50.0	DEGREES F
AIR VISCOSITY	0.0365	SLUGS/FT-SEC*10000
PRESS/FT OF WATER	0.430	PSI/FT

ORI NO.	DIAMETER (INCHES)	DEPTH (FEET)
1	1.315	9.1
2	1.436	9.5
3	1.436	9.6
4	1.436	9.8
5	1.436	9.9

TABLE B-6 (continued)

LOCATION 1 IS IN MANIFOLD APPROACHING ORIFICE
LOCATION 2 IS IN MANIFOLD DOWNSTREAM OF ORIFICE
LOCATION 3 IS OUTSIDE OF ORIFICE

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	4.52	1.5950	1.0000	4.390	3.943	0.00315	0.0239	0.198E 05
2	8.73	1.4994	0.9338	4.389	4.116	0.00315	0.0294	0.364E 05
3	11.78	1.0757	0.6744	4.389	4.246	0.00315	0.0220	0.491E 05
4	14.82	1.0736	0.6731	4.388	4.246	0.00315	0.0211	0.617E 05
5	17.35	0.8828	0.5597	4.388	4.290	0.00315	0.0216	0.723E 05

TOTAL AIR FLOW 367.59 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	7.92	2.9446	1.0000	5.309	3.943	0.00331	0.0276	0.347E 05
2	16.80	3.2980	1.1200	5.307	4.116	0.00331	0.0305	0.738E 05
3	25.20	3.1203	1.0597	5.304	4.246	0.00331	0.0192	0.110E 06
4	33.58	3.1144	1.0577	5.300	4.246	0.00331	0.0185	0.147E 06
5	41.79	3.0476	1.0350	5.276	4.290	0.00331	0.0193	0.181E 06

TOTAL AIR FLOW 931.49 SCFM

TABLE B-6 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	10.06	3.9289	1.0000	6.389	3.943	0.00347	0.0223	0.462E 05
2	21.63	4.5148	1.1509	6.383	4.116	0.00347	0.0195	0.995E 05
3	32.86	4.3771	1.1158	6.360	4.246	0.00347	0.0184	0.151E 06
4	44.07	4.3685	1.1136	6.372	4.246	0.00347	0.0178	0.203E 06
5	55.14	4.3137	1.0996	6.368	4.290	0.00347	0.0172	0.256E 06

TOTAL AIR FLOW 1299.82 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	11.66	4.7650	1.0000	7.389	3.943	0.00364	0.0215	0.562E 05
2	25.24	5.5441	1.1635	7.384	4.116	0.00364	0.0190	0.122E 06
3	38.52	5.4244	1.1384	7.375	4.246	0.00364	0.0179	0.186E 06
4	51.79	5.4134	1.1361	7.384	4.246	0.00364	0.0174	0.249E 06
5	64.94	5.3627	1.1254	7.351	4.290	0.00363	0.0170	0.312E 06

TOTAL AIR FLOW 1590.57 SCFM

TABLE B-6 (continued)

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	12.96	5.5338	1.0000	9.388	3.943	0.00380	0.0209	0.652E 05
2	28.13	6.4760	1.1704	9.382	4.116	0.00380	0.0186	0.148E 06
3	43.05	6.8666	1.1906	9.371	4.246	0.00380	0.0176	0.217E 06
4	57.95	6.8998	1.1488	9.356	4.346	0.00380	0.0171	0.291E 06
5	73.74	6.8067	1.1332	9.334	4.290	0.00380	0.0166	0.364E 06

TOTAL AIR FLOW 1661.96 SCFM

DPI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.04	6.2549	1.0000	9.392	3.943	0.00387	0.0215	0.720E 05
2	30.54	7.3477	1.1747	9.380	4.116	0.00387	0.0189	0.161E 06
3	46.88	7.8418	1.1538	9.366	4.246	0.00387	0.0174	0.234E 06
4	63.07	7.8440	1.1507	9.348	4.345	0.00384	0.0169	0.311E 06
5	79.23	7.1794	1.1479	9.326	4.290	0.00385	0.0165	0.415E 06

TOTAL AIR FLOW 2115.35 SCFM

TABLE B-6 (continued)

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	14.97	6.5445	1.0000	10.398	3.943	0.00413	0.0201	0.819E 05
2	32.60	8.1784	1.1777	10.378	4.116	0.00413	0.0180	0.178E 06
3	50.04	8.0795	1.1635	10.362	4.246	0.00413	0.0172	0.274E 06
4	67.45	8.0617	1.1609	10.340	4.246	0.00412	0.0167	0.369E 06
5	84.77	8.0116	1.1537	10.314	4.290	0.00412	0.0164	0.463E 06

TOTAL AIR FLOW 2356.55 SCFM

ORI NO.	V1 (FPS)	Q3 (SCFS)	Q3 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (SLUG/FT3)	F FACT	REY NO.
1	15.78	7.6108	1.0000	11.387	3.943	0.00430	0.0199	0.868E 05
2	34.40	8.9785	1.1798	11.376	4.116	0.00430	0.0178	0.196E 06
3	52.84	8.8636	1.1672	11.357	4.246	0.00429	0.0170	0.300E 06
4	71.25	8.8634	1.1646	11.332	4.246	0.00429	0.0166	0.405E 06
5	89.57	8.8122	1.1579	11.302	4.290	0.00428	0.0163	0.508E 06

TOTAL AIR FLOW 2588.96 SCFM

TABLE B-6 (continued)

DPI NO.	W1 (PPS)	W2 (PPS)	P2 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LUG/FT3)	F FACT	REY NO.
1	16.49	6.8734	1.0000	18.387	3.943	0.00448	0.0196	0.8745 05
2	26.98	9.7513	1.1815	18.374	4.116	0.00446	0.0177	0.2125 06
3	33.10	9.6484	1.1701	18.353	4.248	0.00445	0.0168	0.1245 06
4	74.60	8.6419	1.1574	18.334	4.248	0.00445	0.0155	0.4412 06
5	99.81	8.5042	1.1419	18.309	4.294	0.00445	0.0153	0.5525 06

TOTAL AIR FLOW 2814.78 SCFM

DPI NO.	W1 (PPS)	W2 (SCFM)	P2 NORMAL	P1 (PSI)	P3 (PSI)	AIR DEN (LUG/FT3)	F FACT	REY NO.
1	17.13	6.8342	1.0000	18.387	3.943	0.00448	0.0194	0.1058 06
2	27.39	9.5167	1.1526	18.372	4.116	0.00446	0.0173	0.2748 06
3	33.50	10.0371	1.1734	18.344	4.248	0.00445	0.0168	0.3585 06
4	77.58	1.0.0044	1.1634	18.318	4.248	0.00445	0.0154	0.4736 06
5	97.99	10.3479	1.1813	18.277	4.294	0.00443	0.0153	0.5456 06

TOTAL AIR FLOW 3005.43 SCFM